NAVAL RESEARCH LABORATORY

NAVAL CENTER FOR SPACE TECHNOLOGY

FAME Component Specification, Reaction Control System, Propellant Tank
for the
Full-sky Astrometric Mapping Explorer (FAME) Spacecraft

NCST-S-FM006 **25 June 2001**

4555 Overlook Avenue, S.W.
Washington, D.C. 20375-5000

RECORD OF CHANGES

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1.0 SCOPE

1.1 Identification

This document applies to the Full-sky Astrometric Mapping Explorer (FAME) observatory program, a NASA Medium Class Explorer (MIDEX) mission.

1.2 Purpose

This specification establishes the performance, design, manufacture, verification, and acceptance requirements for the hydrazine propellant tank of the FAME observatory.

1.3 System Overview

The FAME observatory will provide the positions, proper motions, parallaxes, and photometry of nearly all stars as faint as 15th visual magnitude with accuracies of 50 microarcseconds (µas) at 9th visual magnitude and 500 µas at 15th visual magnitude. Stars will be observed with the Sloan Digital Sky Survey g', r', i', and z' filters for photometric magnitudes. This is accomplished by a scanning survey instrument with a mission life of 2.5 years and an extended mission to 5 years. For more information about the FAME science objectives, refer to NCST-D-FM001. For more information about the FAME mission requirements, refer to NCST-D-FM002.

1.3.1 FAME Mission Diagram

Figure 1-1 shows a block diagram of the FAME mission. To accomplish the mission requirements, the FAME mission requires a space segment (flight vehicle) and a ground segment.

1.3.1.1 Flight Vehicle Description

The FAME flight vehicle consists of the mated FAME observatory and the interstage assembly (see Figure 1-2).

1.3.1.1.1 FAME Observatory

The FAME observatory consists of a spacecraft (S/C) bus and a single scanning survey instrument (referred to as instrument or payload).

1.3.1.1.1.1 S/C Bus

The S/C bus consists of the flight hardware/software required to support the payload.

1.3.1.1.1.2 FAME Instrument Payload

The FAME instrument P/L consists of a scanning survey instrument with a single telescope looking at two fields of view simultaneously. The two fields of view will be imaged onto a single focal plane populated with CCDs. The CCDs will be clocked in time delay integration (TDI) mode to accumulate stellar images as the observatory rotates.

1.3.1.1.2 FAME Interstage Assembly

The FAME interstage assembly consists of the mating structure between the Expendable Launch Vehicle (ELV) and the observatory. The interstage also houses the Apogee Kick Motor (AKM).

1.3.1.2 Ground Segment

The ground segment: (i) transmits commands to the observatory; (ii) receives and archives downlinked housekeeping and status telemetry and science data; (iii) monitors and trends S/C bus and instrument housekeeping and status telemetry data; and (iv) analyzes and reduces science data to produce mission science deliverables.

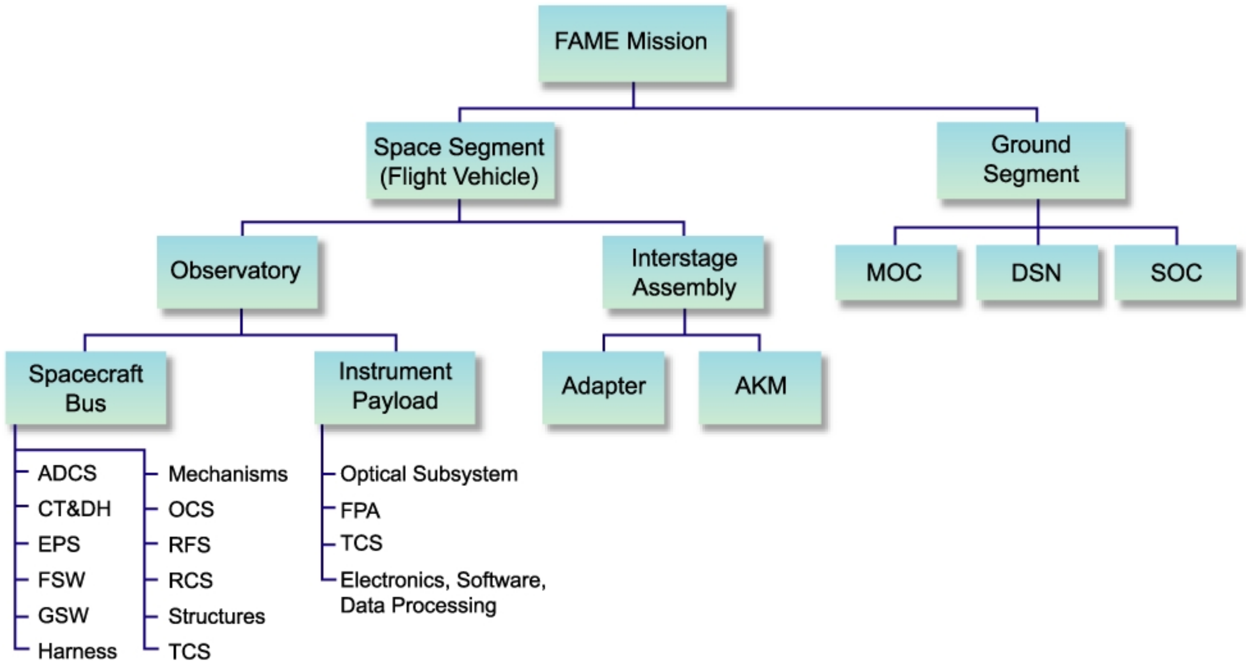


Figure 1-1. FAME Mission Block Diagram

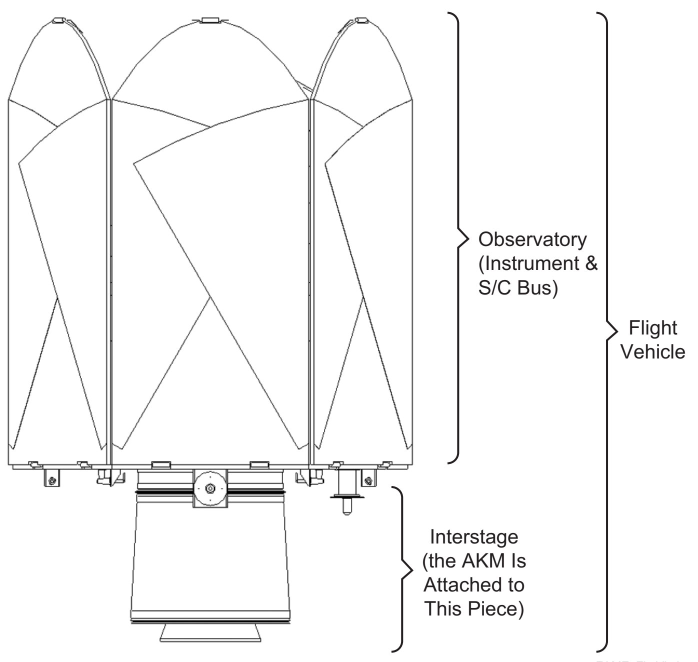


Figure 1-2. FAME Space Segment Taxonomy

1.4 Document Overview

This specification establishes the performance, design, manufacture, verification, and acceptance requirements for the hydrazine propellant tank of the FAME observatory. It also identifies and describes the characteristics, design, construction, documentation, logistics, personnel, training, and qualification requirements for the FAME program. This document is organized as follows:

a. Section 1.0, *Scope:* Purpose and contents of this document, and an overview of the FAME program.

b. Section 2.0, *Referenced Documents:* A list of documents referenced in or required for use with this document.

c. Section 3.0, *Requirements:*

   1. Paragraph 3.1 provides a comprehensive definition of the hydrazine propellant tank.
   2. Paragraphs 3.2 through 3.4 specify the performance and physical characteristics of the hydrazine propellant tank.
   3. Paragraph 3.5 specifies the minimum design and construction requirements for the hydrazine propellant tank.
   4. Paragraph 3.6 describes the documentation that the supplier must provide with the hydrazine propellant tank.

d. Section 4.0, *Quality Assurance Provisions:* Details the tests to be conducted and the methods of test verification that will be employed.

e. Section 5.0, *Preparation for Delivery:* Provides guidance for preparing the hydrazine propellant tank for delivery.

f. Section 6.0, *Notes:* Provides additional information that is not contractually binding. Included are a glossary and list of acronyms.

The performance requirements herein are applicable during nominal operations, maintenance, or contingency events. Requirements for earlier or other staged events are noted. Each requirement, unless otherwise noted, represents the required performance of the hydrazine propellant tank from the time of its activation through end of mission life.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

The following documents of the exact issue shown form a part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this document, the contents of this document shall be considered a superseding requirement. Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the contracting agency or as directed by the contracting officer. Documents beginning with the control number “SSD” and “NCST” are program documents controlled by the NRL.

2.1.1 Specifications

2.1.1.1 Military Specifications

Most active military specifications are available on-line from: http://astimage.daps.dla.mil/quicksearch/

Number	Title	Paragraph Reference
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys	3.5.2.4.8.2
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys	3.5.2.4.8.2
MIL-DTL-31000A	Technical Data Packages	3.6.1
MIL-C-81302	Cleaning Compound, Solvent, Trichlorotrifluoroethane (Type 1) (Freon 113)	3.2.2.3
MIL-I-6866	Inspection, Penetrant Method of	3.5.2.5.1, 4.4.3.11.1, 4.4.3.11.5
MIL-P-26536	Propellant Amendment 2, Hydrazine, High Purity Grade	3.1.2, 3.2.2.1
MIL-P-27401	Propellant Pressurizing Agent, Nitrogen	3.2.2.3
MIL-P-27407	Propellant Pressurizing Agent, Helium	3.2.2.3
MIL-Q-9858	Quality Program Requirements	4.1
MIL-S-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems	3.5.2.4.8.1
MIL-S-7742	Screw Threads, Standard, Optimum Selected Series, General Specification for	3.5.1.4
MIL-S-8879	Screw Threads, Controlled Radius Root, With Incorporated Minor Diameter, General Specification For	3.5.1.4
MIL-T-152	Treatment, Moisture and Fungus Resistant, of Communications, Electronic and Associated Electrical Equipment	3.5.2.4.10
MIL-W-8611	Welding, Metal Arc and Gas, Steels, and Corrosion and Heat Resistant Alloys, Process for	3.5.2.5.1
MIL-W-46132	Welding, Fusion, Electron Beam, Process for	3.5.2.5.1

2.1.1.2 Federal Specifications

Number	Title	Paragraph Reference
QQ-P-35	Passivation Treatment for Corrosion Resistant Steel	3.5.2.4.8.1
TT-I-735A	Isopropyl Alcohol	3.2.2.3

2.1.2 Standards

2.1.2.1 Military Standards

Most active military standards are available on-line from: http://astimage.daps.dla.mil/quicksearch/

Number	Title	Paragraph Reference
MIL-STD-129N	Marking for Shipment and Storage	5.1.3
MIL-STD-453	Inspection, Radiographic	3.5.2.5.1
MIL-STD-464	Depart of Defense Interface Standard for Electromagnetic Environmental Effects Requirements for Systems	3.2.7.2
MIL-STD-794	Parts and Equipment, Procedures for Packaging	5.2
MIL-STD-810F	Environmental Test Methods	3.4.2.2
MIL-STD-889B	Dissimilar Metals	3.5.2.4.5
MIL-STD-1522A	Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems	3.1.1, 3.2.1, 3.4.2, 3.5, 3.5.1, 3.5.1.2, 3.5.1.3, 3.5.2.4.2.1, 4.4.3.10, 4.4.3.10.4.5, 4.4.3.10.4.6
MIL-STD-1246C	Product Cleanliness Levels and Contamination Control Program	3.5.2.5.4, 3.5.2.5.5, 3.5.2.5.6
MIL-STD-1523	Age Controls of Age Sensitive Elastomeric Material	3.5.2.2
MIL-STD-961D	Specification Practices	3.6.3
MIL-STD-45662	Calibration System Requirements	4.4.3.9

2.1.2.2 Federal Standards

Number	Title	Paragraph Reference
FED-STD-209E	Clean Room and Work Station Requirements, Controlled Environment	3.5.2.5.4
FED-STD-H28	Screw Threads, Standards for Federal Service; General Specification for	3.5.1.4

2.1.3 Military Handbooks

Most active military handbooks are available on-line from: http://astimage.daps.dla.mil/quicksearch/

Number	Title	Paragraph Reference
MIL-HDBK-217F	Reliability Prediction of Electronic Equipment	3.3

2.1.4 Other Publications

NASA Technical Standards are available on-line from: http://www.hq.nasa.gov/office/codeq/doctree/index.htm

Number	Title	Paragraph Reference
SAE-AMS2680B	Electron-Beam Welding for Fatigue Critical Applications	3.5.2.5.1
SAE-AMS2681B	Welding, Electron-Beam	3.5.2.5.1

Number	Title	Paragraph Reference
EWR 127-1, 31 Oct 1997 with 23 Oct 2000 Change Pages	Eastern and Western Range Regulation 127-1, Range Safety Requirements. Available on-line at http://www.patrick.af.mil/45sw/rangesafety/library.htm	3.1.1, 3.2.1, 3.3.5.1, 3.4.2, 3.5, 3.5.1, 3.5.1.2, 3.5.1.3, 3.5.2.4.2.1, 4.4.3.10, 4.4.3.10.4.5, 4.4.3.10.4.6
GSFC-410-MIDEX-001 Rev C	MIDEX Assurance Guidelines	3.5.2.1
MSFC-SPEC-522B	Design Criteria for Controlling Stress Corrosion Cracking	3.5.2.4.2, 3.5.2.4.7
MSFC-STD-481	Standard Radiographic Inspection and Acceptance Standard for Fusion Welded Joints in Stainless and Heat Resistant Metals	3.5.2.5.1
NAS-1514	Radiographic Standard for Classification of Fusion Weld Discontinuities	3.5.2.5.1
SP-R-0022	Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications, Specifications for	3.5.2.4.1

2.1.5 FAME Project Documents

Available to registered users at http://team8200.nrl.navy.mil/

Number	Title	Paragraph Reference
NCST-D-FM001	FAME Science Requirements Document	1.3
NCST-D-FM002	FAME Mission Requirements Document	1.3
NCST-D-FM007	FAME Contamination Control Plan	3.4.1
NCST-TP-FM001	FAME System Test Plan	3.4.2.4

2.2 Order of Precedence

In the event of a conflict between the text of this specification and the references cited herein, the documents shall rank in the following order of precedence:

1. Purchase Agreement
2. Statement of Work
3. This specification
4. Applicable documents listed in section 2.0

Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 REQUIREMENTS

3.1 Item Definition

This specification establishes the requirements for the performance, design, test, qualification, acceptance, and delivery of a hydrazine propellant tank for use on the FAME Program. The hydrazine propellant tank will be used in the reaction control system of a space vehicle. The hydrazine propellant tank is also referred to as propellant tank, tank, pressure vessel, the product, and/or item within this specification.

3.1.1 Defining Characteristics

The hydrazine propellant tank shall consist of a metallic pressure vessel shell and metallic diaphragm positive expulsion device that is capable of supporting 352 lbs of liquid hydrazine and expelling it under operating pressures of up to 450 psig. The propellant tank shall have girth mounts, a liquid volume of 10,000 cubic inches, polar inlet and outlet ports, and all welded construction. The propellant tank shall be qualified to the anticipated pressure and flight loads including stress analysis, failure mode determination analysis, fracture mechanics safe-life analysis, and acceptance and qualification hardware testing. The propellant tank shall expel the propellant while maintaining lateral center of gravity control of the propellant to within 0.05 inch of the expulsion axis. This propellant tank for hydrazine usage is classified as “hazardous” under the requirements of EWR 127-1 and MIL-STD-1522.

3.1.2 Basic Function

The tank’s primary function is to support and deliver liquid hydrazine (N_2H_4) propellant, in accordance with MIL-P-26536, to the space vehicle thrusters in order to provide spin, attitude control, and fine ΔV maneuvers for a space vehicle. The tank is required to function within the performance parameters specified in this document over the ranges of specified operating conditions listed herein including operating pressures of 450 psig.

3.1.3 Intended Use

This section provides additional information about the FAME mission and propulsion system that contains the hydrazine propellant tank being specified to assist in the tank design. The information in this section does not require verification, and shall not be used to diminish any stated requirement elsewhere herein.

The hydrazine propellant tank is being designed for blowdown operating to store both the liquid propellant and pressurization gas for use by the FAME spacecraft. Since the exact flight propellant load has not been determined, the tank is being sized and performance specified for a range of propellant and pressurization options. The liquid hydrazine propellant load variation at the beginning of life (BOL) ranges from a mass of 352 to 150 lbs. Pressurization options range from BOL pressures of 450 to 200 psig. The mounting flange shall be designed for stress loads due to the maximum propellant load. The propellant tank may use an auxiliary pressurization system, either regulated or unregulated, in which case the hydrazine tank could be filled to the 97% fill fraction.

3.1.3.1 Integration

The hydrazine propellant tank will be mounted in a spacecraft structure with propellant inlet and outlet ports in the axial direction of both launch vehicle and interstage solid rocket motor thrust. Conceptually, the liquid hydrazine will be supported by the tank wall rather than the diaphragm during solid rocket motor firings. The propellant tank will be mounted at the girth on a single honeycomb panel or a series of solid machined aluminum mounting brackets. The inlet and outlet tubes will be connected to the hydrazine system plumbing, fill valves, and flow control valves. The flight telemetry system will have both pressure and temperature monitoring of the propellant tank conditions. The propellant tank may or may not be covered with a thermal blanket and heater dependent on system thermal analysis.

3.1.3.2 Testing

The tank will be acceptance tested by the NRL before integration into the flight spacecraft. After installation in the flight system, the system will be subjected to acceptance testing including a system level proof pressure test. During storage, the propellant tank will be pressurized with a dry cover gas to a pressure of approximately 10 psig or less depending on the specific diaphragm characteristics. The cover gas prevents water condensation within the tank, provides gross leak detection, and prevents debris or contamination from entering the propellant system while not in use.

3.1.3.3 Transportation

The spacecraft will be transported in such a fashion to prevent environments from exceeding flight loads or conditions as specified in this document.

3.1.3.4 Protection

After initial integration into the spacecraft, the propellant tank is protected from damage by the spacecraft primary thrust tube structure and secondary propulsion honeycomb panel structure.

3.1.3.5 Propellant Loading

Propellant will be loaded at the Kennedy Space Center in a hazardous processing area. The propellant loading will entail propellant tank venting of the cover gas, evacuation of the gas side of the tank, evacuation of the liquid side of the tank, hydraulic loading of propellant, and finally pressurization of the gas side of the propellant tank. The tank will be pressurized before the spacecraft is installed on the Delta 2925 launch vehicle. Propellant offloading from the propellant tank must be possible in case unforeseen contingencies arise.

3.1.3.6 Spin Balance

The loaded and pressurized hydrazine tank, integrated into the spacecraft and interstage assembly, will be spin balanced (static and dynamic alignment) before encapsulation in the launch vehicle fairing. It is anticipated that the spacecraft will be spin balanced at 60 rpm.

3.1.3.7 Launch

The loaded propellant tank will be pressurized and the diaphragm activated during launch on the Delta 2925 launch vehicle. The anticipated launch environments are included in this specification.

3.1.3.8 Transfer Orbit Operations

The loaded propellant tank will be used in Geo-synchronous transfer orbit for spacecraft acquisition, slew maneuvers, delta velocity, spin control, and active nutation control before and potentially during the firing of an on-board solid rocket motor (SRM) to propel the spacecraft into GEO. It is anticipated that the spacecraft will be spin stabilized at 60 rpm and that the SRM stage will impart 5 g's axial acceleration. Moments after the SRM maneuver, the tank reaches the maximum expected temperature due to thermal soakback from the solid rocket motor case. The propellant tank will also feed the thrusters for final maneuvering into the mission orbit.

3.1.3.9 Geo-Synchronous Mission Operations

Once established in the mission orbit for science data collection, the propellant tank environment becomes very stable. The propellant system is intentionally disabled for the majority of the five years of science data collection. The thermal and dynamic environment are anticipated to be quite benign including tight tolerances on system temperature fluctuation (±2°C) for structural stability and to minimize jitter disturbances. This portion of the mission requires that the propellant center of gravity must be characterized and remain within close tolerance to the geometric axis of expulsion.

3.2 Performance Characteristics

3.2.1 Design and Performance

The propellant tank shall be designed and shall perform in excess of the requirements criteria of MIL-STD-1522A and EWR 127-1 with October 2000 change pages. In case of a conflict between these two documents, the requirements of the EWR shall apply.

3.2.2 Operating Media

3.2.2.1 Propellants and Pressurant Gasses

The propellant tank shall meet the performance requirements specified herein when operated with anhydrous hydrazine (N_2H_4) per MIL-P-26536.

3.2.2.2 Chemical Compatibility

All materials used in the fabrication of the propellant tank shall be chemically compatible for five years of hydrazine storage without degradation, alteration of the propellant, or causing evolution of gaseous byproducts.

3.2.2.3 Fluids and Solvents

The hydrazine propellant tank shall be capable of operating after exposure to the following fluids filtered to remove particles greater than 15 microns:

a. Helium per MIL-P-27407

b. Nitrogen per MIL-P-2740l

c. Deionized water with a resistance of >50,000 ohm centimeters

d. Isopropyl Alcohol per TT-I-735, Grade A

e. Freon 113, Type 1, Trichlorotrifluoroethane per MIL-C-81302

3.2.3 Pressure Ratings

3.2.3.1 Operating Pressure

The propellant tank shall perform within the limits of this specification over a normal propellant pressure range of 450 to -15 psig. The tank will have a Maximum Expected Operating Pressure (MEOP) of 450 psig.

3.2.3.2 Reverse Pressure

The propellant tank shall be designed such that it can withstanding reverse pressure from conditions when the internal volume is evacuated and the external pressure is 30 psid without collapse, performance degradation, or permanent distortion.

3.2.3.3 Outlet Port Pressurization

The propellant tank design shall allow the tank outlet port to be pressurized to 50 psid greater than the inlet port.

3.2.3.4 Proof Pressure

The propellant tank shall withstand a minimum internal pressure of 563 psig for 5 minutes duration when pressure is applied simultaneously to the inlet and outlet ports without internal damage, permanent distortion, or performance degradation. No material yielding is permitted at proof pressure.

3.2.3.5 Burst Pressure

The propellant tank shall be capable of withstanding a minimum internal pressure 675 psig for 5 minutes duration without rupture when pressure is applied to the inlet and outlet ports simultaneously. The propellant tank will not be required to function after exposure to burst pressure testing.

3.2.3.6 Minimum Diaphragm Rolling Pressure

The minimum initial diaphragm rolling pressure shall be 17 psid from the gas to liquid side of the diaphragm to prevent diaphragm motion during evacuation of the liquid side of the tank. The subsequent differential pressure to roll the diaphragm for propellant expulsion shall be minimized.

3.2.3.7 Transient Line Pressures

The propellant tank shall not be susceptible to damage from transient hydraulic surge pressures in the liquid port generated by opening and closing valves within a hydrazine propellant system. Pressure surges will be high frequency, oscillatory in nature, and with frequency dependent on the diaphragm mechanical properties. Surge pressures will be limited to (1000) psig maximum and will be damped out by elasticity of the diaphragm material.

3.2.3.8 Cycle Requirements

The propellant tank shall be qualified to perform a minimum of 25 pressurization cycles without performance degradation. A pressure cycle shall be defined as an event where the internal pressure exceeds 100 psig. Transient pressures as defined in paragraph 3.2.3.7 shall not count against the cycle life limits. The qualification shall be 100 MEOP cycles minimum demonstration.

3.2.4 Propellant Expulsion

The propellant tank shall be capable of expelling any combination of gas and liquid volumes as listed in the tank volume requirements within the requirements of this specification.

3.2.4.1 Expulsion Cycles

The propellant tank shall be capable of performing one complete propellant expulsion cycle.

3.2.4.2 Expulsion Efficiency

The propellant tank shall have a minimum expulsion efficiency of 97% with a liquid outlet pressure of 100 psig and gas inlet pressure of 150 psig.

3.2.4.3 Diaphragm Differential Pressure

The diaphragm shall be designed to support a maximum possible differential pressure of 225 psid from the gas to liquid side of the diaphragm without rupture.

3.2.4.4 Propellant Depletion

The propellant tank shall withstand propellant depletion without structural or performance failure.

3.2.4.5 Liquid Offloading

The propellant tank shall be designed such that liquids, including cleaning fluid or propellants, may be offloaded from the tank without damage to the tank or degradation of the tank's future performance. The propellant tank shall be capable of offloading and reloading after diaphragm activation without performance degradation.

3.2.5 Thermal

3.2.5.1 Operating Propellant Temperature

The propellant tank shall perform within specification limits over a propellant temperature range of 5˚C to 50˚C.

3.2.5.2 Qualification Temperature

The propellant tank shall perform within specification limits after dry exposure to temperatures from -10˚C to +60˚C.

3.2.5.3 Propellant Expansion

The propellant tank performance shall not be degraded by thermal expansion of the propellant over the operating temperature range specified in paragraph 3.2.5.1.

3.2.5.4 Tank Resistance Heater

The propellant tank shall support the use of bonded strip heaters to maintain tank temperature control. Such a heater will provide a maximum localized heating of 3 watts per square inch. This heat loading, or resultant local temperature shall not be detrimental to the tank design or performance as specified.

3.2.6 Leakage

3.2.6.1 Internal Leakage

Internal leakage across or through the diaphragm shall not exceed 1 x 10^{-6} scc/sec when pressurized with helium over the propellant tank operating pressure range. Leakage shall be measured across the diaphragm from the liquid to gas side with a maximum differential pressure of 50 psid from the liquid to gas side of the diaphragm.

3.2.6.2 External Leakage

The propellant tank external leakage shall not exceed 1 x 10^{-6} scc/sec when the inlet and outlet ports of the propellant tank are pressurized with helium at 450 psig.

3.2.7 Electrical Characteristics

3.2.7.1 Electrical Ground Plane

The propellant tank shall be compatible with an electrical design for which the spacecraft electrical ground plane includes the propellant tank and primary spacecraft structure.

3.2.7.2 Electrical Bonding

The propellant tank shall provide for electrical bonding in accordance with MIL-STD-464 without deterioration of the specified performance.

3.2.7.3 Electro-static Discharge (ESD)

The propellant tank shall not be sensitive to ESD.

3.2.8 Physical Characteristics

3.2.8.1 Tank Geometric Axis

The propellant tank geometric axis shall be as defined in Figure 3-1.

3.2.8.2 Z Axis Center of Gravity

The propellant tank supplier shall provide the tank center of gravity versus expulsion in the Z axis of the tank.

3.2.8.3 X, Y Plane Mass Imbalance

The propellant tank shall expel the propellant while not exceeding 10 lb-inches of mass imbalance from the Z axis.

3.2.8.4 Weight

The weight of the propellant tank shall be the minimum attainable without degradation of performance or reliability. The tank shall not exceed either a dry weight 41.0 lb or a total inert weight, including dry tank and unusable propellant, of 52 lbs as demonstrated by expulsion efficiency testing. For this calculation, use hydrazine density of 8.415 pound per gallon.

3.2.8.5 Volume

The total usable internal propellant tank volume shall be the summation of the liquid and gas side volumes exclusive of the diaphragm volume. The supplier shall design the tank total volume and liquid volume within the envelope, performance, and mass allocations of this specification. The supplier shall measure the actual tank total volume prior to delivery.

3.2.8.5.1 Liquid Volume

The propellant tank shall be capable of supporting a liquid volume range of 10,000 cubic inches to 200 cubic inches to support the customer's flight propellant requirements. The supplier shall measure the actual tank liquid volume.

3.2.8.5.2 Gas Volume

The propellant tank shall be capable of supporting all gas volume ranges related to the difference between the total tank volume and liquid volume ranges as specified. The supplier shall design the gas volume as necessary to meet these specifications.

3.2.9 Interface and Envelope

The propellant tank mechanical envelope and physical interfaces are defined in Figure 3-1.

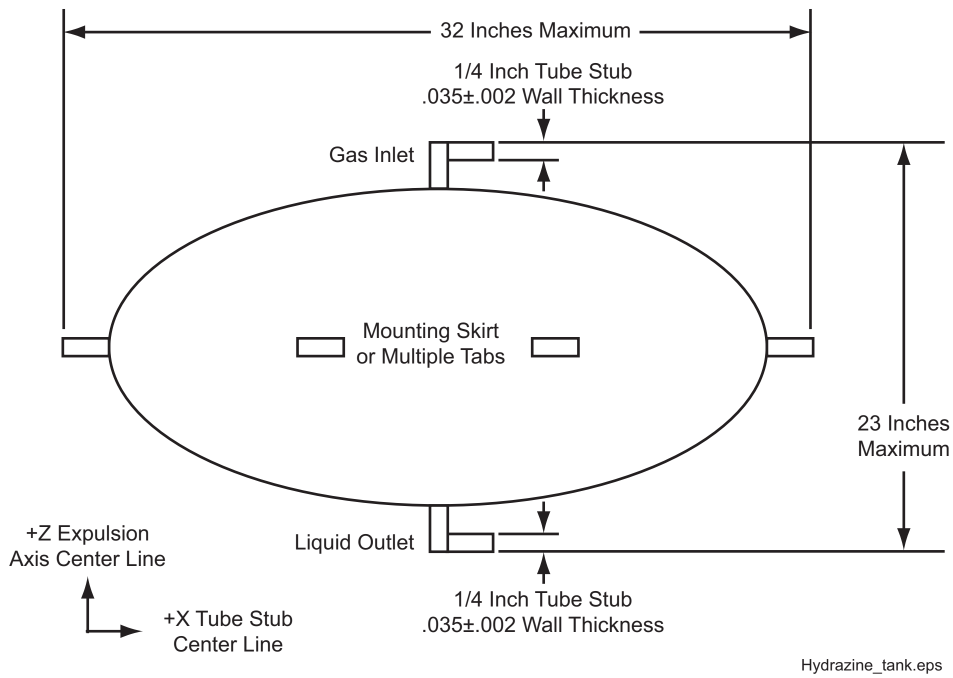


Figure 3-1. Propellant Tank Envelope Drawing

3.2.9.1 Detailed Mechanical Interface Control Drawing (ICD)

The propellant tank physical interface shall be designed and defined by the supplier for customer approval.

3.2.9.1.1 ICD Configuration Control

The propellant tank ICD shall be maintained under configuration control, and shall not be changed without customer approval.

3.2.9.2 Tubing Interface

The propellant tank shall be supplied with inlet and outlet tubes with one inch minimum length, 0.25 inch outside diameter, 0.035±0.002 inch wall thickness, and 304L CRES construction.

3.2.9.3 Special Installation Requirements

The supplier shall identify any special installation requirements for the propellant tank to prevent mechanical over-constraint or to maintain expulsion center of gravity requirements.

3.2.9.4 Tank Mounting Flange or Skirt

The hydrazine propellant tank shall be designed and equipped with an appropriate mounting skirt or multiple flanges (tabs) accommodating a rigid bolted mechanical interface designed to support the loaded propellant tank under the loads specified herein.

3.2.9.4.1 Mounting Flange Alignment

The propellant tank mounting flange interface shall be perpendicular to the predicted expulsion centerline within ±0.1°.

3.3 Reliability

As part of the design process, the supplier shall perform a reliability analysis on the propellant tank using the parts failure rates of MIL-HDBK-217. Reliability calculations shall not include those factors applicable to launch, ascent, and flight vehicle or observatory separation operations. The reliability allocations shall ensure that the overall science mission requirements are met under all reasonable conditions for storage, transportation, testing, and operations for a 5 year mission when operated within the criteria of paragraphs 3.1.3.7 through 3.1.3.9 herein. The predicted reliability shall be greater than .995 for a five year mission.

3.3.1 Shelf Life

The propellant tank shall meet all performance requirements specified herein for a period of 6 years minimum after receipt by the customer when suitably packaged and protected per the requirements of Section 5.0.

3.3.2 Operating Life

After 6 years of storage, the propellant tank shall perform within the limits of this specification for 5 years of hydrazine exposure, 25 pressure cycles, and ground processing with the fluids listed in 3.2.2.3.

3.3.3 Maintainability

There shall be no scheduled maintenance service on the propellant tank.

3.3.4 Interchangeability

Assemblies, components, and parts having identical part numbers shall, where practicable, meet the requirements for an interchangeable item as defined in paragraph 6.1.4.

3.3.5 Safety

The propellant tank shall not present noncontrollable health hazards. The propellant tank shall be designed such that no single credible failure or single operator error can result in a critical hazard. The supplier shall document any hazards to provide a basis for reducing risk to an acceptable level, along with any necessary personnel protection procedures. No health hazards shall exist when the propellant tank is removed, maintained, installed, or in storage. The propellant tank and its associated ground support equipment (GSE) shall be capable of being safely stored, handled, transported, installed, and checked out at all times prior to launch, in accordance with procedures agreed to between NRL and the supplier.

3.3.5.1 Safety Compliance

The propellant tank shall be compliant with the regulations of the Eastern Test Range, EWR 127-1 with October 2000 change pages, as applicable to aerospace flight systems launching from the Eastern Range. All non-compliances to these standards require customer approval before implementation and the submittal of a waiver for technical justification. In general, cost is not a technical justification. The supplier is responsible for requirements verification.

3.4 Environmental Conditions and Requirements

The propellant tank shall be designed and qualified to operate within the specification parameters herein without refurbishment or adjustment during and after exposure, as applicable, to all combinations of operating and non-operating environments. The propellant tank shall be designed to withstand testing both at the supplier as a component and at the customer facilities as an integral part of the FAME spacecraft.

3.4.1 Ground Handling, Integration, and Prelaunch Environments

The propellant tank shall meet the requirements of this document without refurbishment or adjustment after exposure to any combination of the ground handling and transportation environments listed below:

a. *Ambient Air Temperature:* External environment is uncontrolled and will range from -10˚C to +40˚C.

b. *Ambient Pressure*: Naturally occurring at sea level to hard vacuum of less than 1 x 10^{-5} torr.

c. *Humidity:* The relative humidity will range from 0% to 100% with condensation in the form of water or ice external to the shipping container only. The internal shipping container environment will be controlled to prevent condensation of moisture or frost on flight hardware.

d. *Acceleration, Vibration, Shock, and Loads:* The propellant tank shall not be exposed to environments greater than those experienced during launch and ascent as listed in paragraph 3.4.2, Qualification Environments.

e. *Cleanliness:* Protective containers or packaging will be used to maintain flight hardware at the cleanliness level specified in NCST-D-FM007.

3.4.1.1 Transportation

The propellant tank shall be capable of meeting the requirements of this specification after shipment by air or surface carrier. The propellant tank shall be designed for flight loads, not ground loads, and special packaging shall be used as necessary to assure that transportation methods do not impose design penalties on the propellant tank. If required, a packaging and transportation plan or procedure shall be developed by the supplier and address special handling requirements as applicable to the unit being delivered.

3.4.2 Qualification Environments

In addition to the pressure cycling and burst demonstration qualification test in accordance with MIL-STD-1522 and EWR 127-1, the propellant tank shall be designed to perform as specified for 5 years after exposure to the environments specified herein for acceleration, vibration, and shock. Pressure and temperature loads shall be added to the environmental loads specified herein for qualification testing.

3.4.2.1 Static Acceleration

The propellant tank shall be qualified to the anticipated flight static acceleration loads. The static load cases are 8 g's axial (z axis) with .5 g's lateral (x-y plane) applied simultaneously and 2.8 g's axial and 10.8 g's lateral also applied simultaneously. The propellant tank will be pressurized and activated but not be required to expel during these conditions. The maximum acceleration at which the propellant tank will require expulsion is 5 g's axial and 2 g's lateral applied simultaneously.

3.4.2.2 Random Vibration

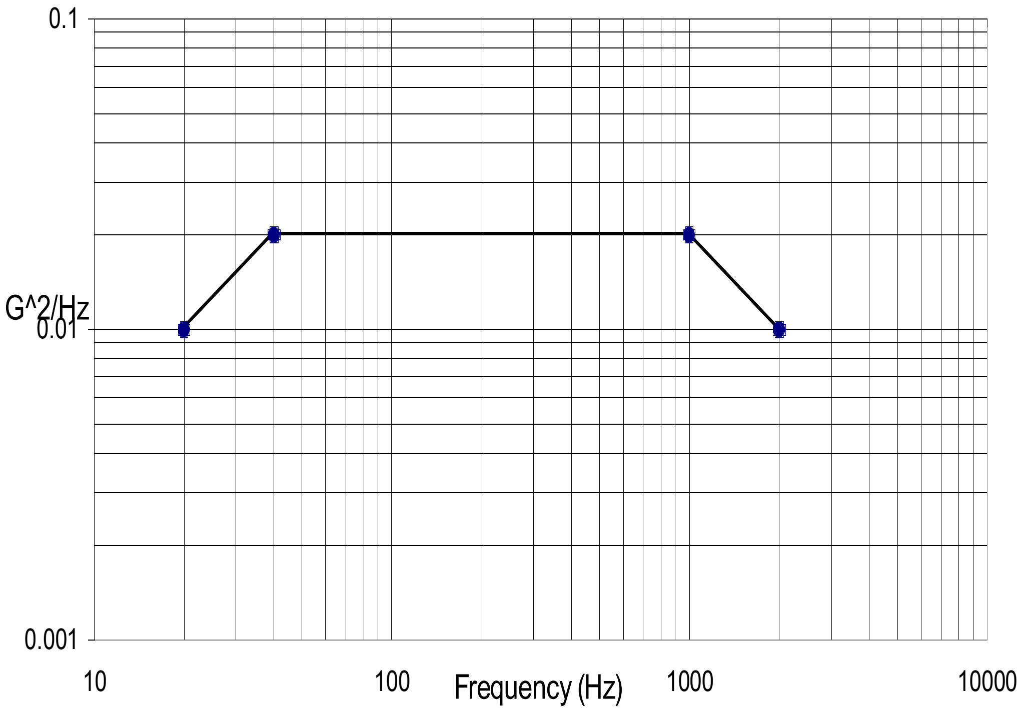
The random vibration environments in the normal and lateral directions for the propellant tank is given in Figure 3-2. The propellant tank will be pressurized and activated during flight vibration conditions, and must be designed to survive it without performance degradation. The protoflight test level for all flight units is +3 dB higher than the expected flight levels for a duration of 2 minutes and the qualification test level for engineering models is +6 dB higher than flight for a duration of 2 minutes in accordance with in MIL-STD-810, Method 514.3, Procedure I.

3.4.2.3 Pyrotechnic Shock

The shock environment shall be as shown in Figure 3-3. The propellant tank will pressurized and activated during this condition in flight, but cannot be activated for ground testing.

3.4.2.4 Integrated Qualification Testing

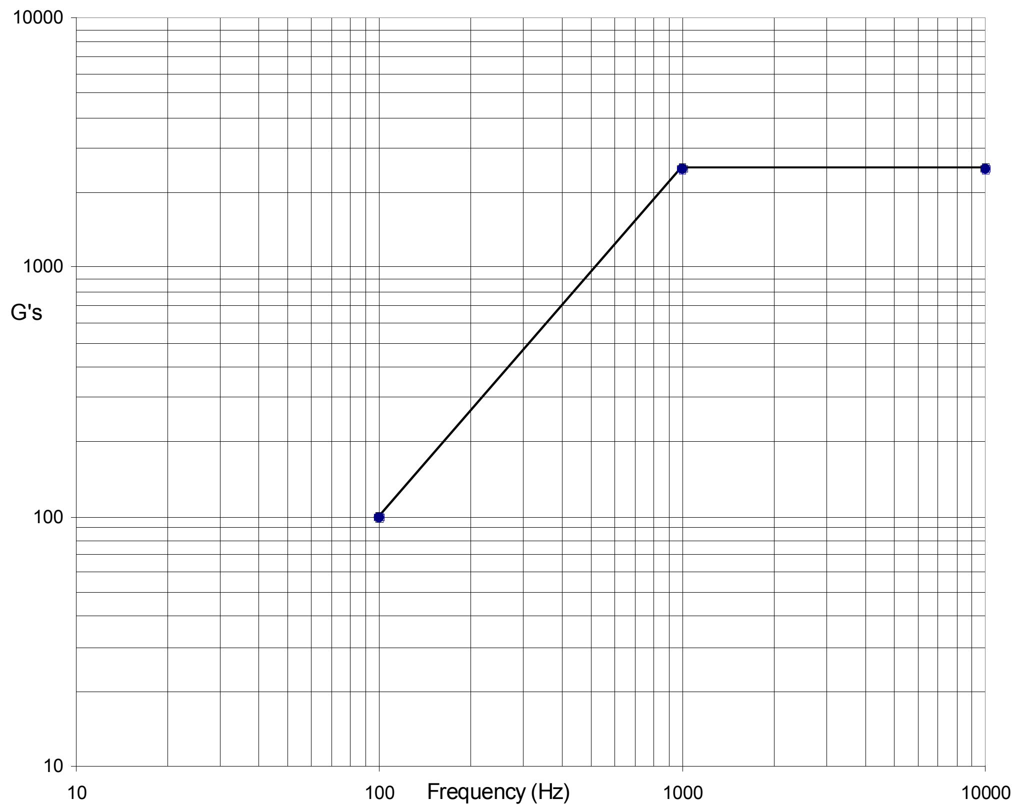
The propellant tank shall be designed to support the qualification activities listed as an integrated part of the FAME spacecraft. Tests include: Modal Survey, Acoustic (see Figure 3-4), Thermal Vacuum, Thermal Balance, Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC), and Spin Balance. The propellant tank supplier is not required to perform these tests, but the propellant tank shall be designed to withstand such testing without degradation of performance. More details about these tests can be found in the FAME System Test Plan, NCST-TP-FM001.



Flt Level Environment	
20	0.01
40	0.02
1000	0.02
2000	0.01
5.8 Grms	

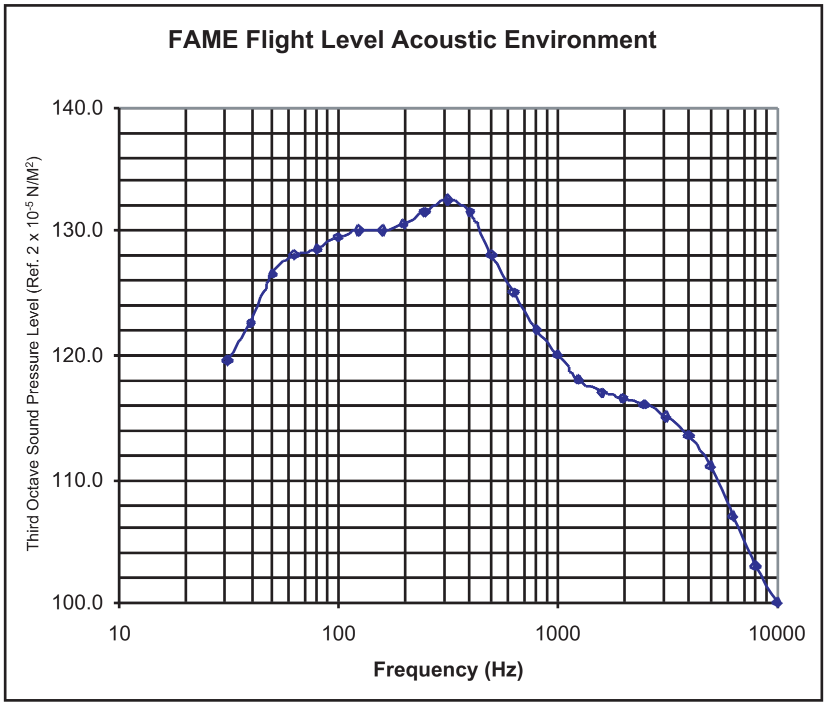
Test Level	Margin Above Flight (dB)	Duration (Minutes)
Non-Flight Prototypes Design & Qualification	6	2
Flight Units Protoflight Acceptance	3	2

Figure 3-2. Random Vibration Environment, Propellant Tank, Empty, Each Axis



Design Environment Shock Response Spectrum Levels		Test Levels	
Frequency (Hz)	G's	Flight	1 Shock per Axis
100	100	Protoflight	2 Shock per Axis
1000	2500		
10000	2500	Qualification	3 Shock per Axis

Figure 3-3. FAME Bus Component Shock Response Design Levels, All Three Axes (Q=10)



One Third Octave Frequency (Hz)	SPL (dB)
32	119.5
40	122.5
50	126.5
63	128.0
80	128.5
100	129.5
125	130.0
160	130.0
200	130.5
250	131.5
315	132.5
400	131.5
500	128.0
630	125.0
800	122.0
1000	120.0
1250	118.0
1600	117.0
2000	116.5
2500	116.0
3150	115.0
4000	113.5
5000	111.0
6300	107.0
8000	103.0
10000	100.0
OA	140.8
Duration	1 Minute

Figure 3-4. Predicted Delta II 7925 9.5-ft Fairing Acoustic Environment

3.5 Design and Contsruction

The following paragraphs describe the general requirements for design and construction that are applicable to the propellant tank. Guidelines for the construction of aerospace pressure systems can be obtained from MIL-STD-1522 and EWR 127-1.

3.5.1 Design Analysis Requirements

Preliminary design analyses are required and must be approved at the Preliminary Design Review (PDR). Final design analyses are required for the Critical Design Review (CDR) and must be included in the Qualification Test Report Package. Detailed analysis requirements can be found in MIL-STD-1522 and EWR 127-1.

3.5.1.1 Stress Analysis

Stress analysis shall be performed for the propellant tank taking into consideration loads and stresses induced by pressure, temperature, and expected flight environments of acceleration, acoustic, random vibration, and shock.

3.5.1.2 Failure Mode Determination

A Failure Mode Determination Analysis shall be performed as defined by MIL-STD-1522 and EWR 127-1 to identify the most likely propellant tank failure mode.

3.5.1.3 Fracture Mechanics Safe Life Analysis

Fracture Mechanics Analysis shall be performed in accordance with MIL-STD-1522 and EWR 127-1. Note that Fatigue Analysis in accordance with MIL-STD-1522 is not acceptable for determining cycle life under the requirements of EWR 127-1.

3.5.1.4 Thread Design

All threads shall be in accordance with MIL-S-7742, MIL-S-8879, or FED-STD-H28.

3.5.2 Parts, Materials, and Processes (PMP)

PMP used for the fabrication of the propellant tank shall be selected to meet the performance, environmental, and reliability goals specified herein. Standard parts shall be used wherever possible. All parts used in the propellant tank shall be compatible with high purity hydrazine.

3.5.2.1 PMP Plan

The supplier shall implement a PMP plan in accordance with the guidelines contained in GSFC-410-MIDEX-001, paragraph 5.1, *Parts*, and paragraph 5.2, *Materials and Processes*.

3.5.2.2 Life Limited Items

The supplier shall obtain approval before use of age critical or time sensitive materials (limited life items) in the propellant tank. Age sensitive materials are defined by MIL-STD-1523.

3.5.2.3 Parts

Parts used in the fabrication and construction of the hydrazine propellant tank shall be of the highest quality and shall be traceable from their origin. The selection, use and control of materials, processes, and parts shall be in accordance with parts lists and processes as defined in the applicable approved manufacturing drawings.

3.5.2.3.1 Parts List

All parts used in the construction of the hydrazine propellant tank shall be listed and provided to the customer.

3.5.2.3.2 Re-Use of Parts

Parts and materials that have been permanently installed in an assembly and are then removed for any reason shall not be used in any item of spaceflight hardware.

3.5.2.3.3 Structural Parts

All structural parts require the use of certified tested raw materials.

3.5.2.4 Materials

3.5.2.4.1 Outgassing

The lowest outgassing materials consistent with design and qualification heritage restraints shall be used. Materials exhibiting total mass loss (TML) of 1.0% or less and collected volatile condensable material (CVCM) values of 0.1% or less shall be used in accordance with SP-R-0022. Any materials that fail to meet these criteria shall be identified to the FAME Project Management Office (PMO).

3.5.2.4.2 Structural Metallic Materials

MSFC-SPEC-522 Table I materials are strongly preferred. MSFC-SPEC-522 Table II and Table III materials should receive careful evaluation and shall be identified at the PDR and CDR.

3.5.2.4.2.1 Material Properties

The hydrazine propellant tank shall use materials with “A” allowable values in accordance with the requirements of MIL-STD-1522 and EWR 127-1.

3.5.2.4.3 Structural Safety Factors

The following structural safety factors shall be used as minimum design criteria:

a. Yield 1.10

b. Ultimate 1.40

c. Local Buckling 1.25

d. Overall Stability 1.40

e. Fitting Factor (single point failure) 1.15

f. Gapping 1.15

3.5.2.4.4 Prohibited Materials

The hydrazine propellant tank shall not use copper, gold, silver, lead, or molybdenum materials. Other metals that oxidize easily shall be minimized.

3.5.2.4.5 Dissimilar Metals

Dissimilar metals as described in MIL-STD-889 shall not be used.

3.5.2.4.6 Magnetic Materials

The use of magnetic materials shall be minimized. The residual dipole of the FAME space segment must be minimized and the use of magnetic materials should be avoided whenever possible. When magnetic materials must be used they shall be identified, along with the field intensity caused by the material, and be approved by the customer.

3.5.2.4.7 Stress Corrosion

Materials shall be selected to control stress corrosion cracking in accordance with MSFC-SPEC-522.

3.5.2.4.8 Metal Finish Requirements

The proper surface treatment, finish material, and application methods are specific to the material used, environment, design, handling, and storage requirements. The following shall apply:

a. Metallic materials shall be corrosion resistant by nature or shall be corrosion inhibited by means of protective coatings.

b. The materials an application process used shall not be detrimental to the parts.

c. Base metals intended for intermetallic contact that form galvanic couples shall be plated with those metals that reduce the potential difference or shall be suitably insulated by a nonconducting finish.

d. Electrical bonding methods shall include provisions for corrosion protection of mating surfaces.

e. Perform fabrication operations prior to the installation of protective finishes

f. Apply parts finish prior to mechanical assembly or after fusion assembly.

g. Finishes that will chip, crack, or scale with age or climatic conditions shall not be used.

3.5.2.4.8.1 Corrosion Resistant Steel

Corrosion resistant steel shall be passivated in accordance with MIL-S-5002 or QQ-P-35.

3.5.2.4.8.2 Aluminum Treatments

Aluminum parts shall be anodized per MIL-A-8625, Type 1, except where Alodine per MIL-C-5541, Class III, is necessary to satisfy electrical bonding requirements.

3.5.2.4.9 Prohibited Finishes

Cadmium and zinc coatings shall not be used.

3.5.2.4.10 Non-metallic materials

Nonmetallic parts shall not have a corrosion stimulating effect on other materials when exposed. Fungus nutrient materials as defined in MIL-T-152 shall not be used.

3.5.2.4.11 Lubricants and Sealants

Lubricants and sealants shall not be used.

3.5.2.4.12 Toxic Products and Formulations

Toxic products and formulations shall meet the applicable Occupational Safety and Health Administration (OSHA) and launch site safety requirements.

3.5.2.5 Processes

3.5.2.5.1 Soldering, Welding, and Other Critical Processes

Soldering, welding, bonding, plating, and other critical processes shall be controlled by procedures or process specifications that have been submitted and approved by NRL prior to first use. Unless alternative techniques and inspection criteria are substituted with prior written customer approval, the following shall apply:

a. Electron beam weld in accordance with MIL-W-46132

b. Fusion Welding shall be performed in accordance with, MIL-W-8611, SAE-AMS2680 and SAE-AMS2681

c. Radiograph welds in accordance with MIL-STD-453 or MSFC-STD-481

d. Interpret radiographs in accordance with NAS-1514 or MSFC-STD-481

e. Penetrant inspect welds in accordance with MIL-I-6866

3.5.2.5.2 Traceability Process

The supplier shall maintain a system for categorizing PMP into sets of homogeneous groups and tracing those parts through the fabrication, assembly, test, and delivery cycles.

a. The propellant tank PMP shall be traceable from the initial vendor of part, material, or component through the completed hardware item.

b. Parts shall be traced by part number, serial number (when available), and lot number.

   1. The supplier shall maintain fabrication records (i.e., travelers) that provide two-way traceability from the first stages of assembly through final acceptance testing.

   2. Specific entries shall be made on the fabrication record as parts are installed.

   3. All piece parts installed shall be identified and documented in order to be traceable to a specific manufacturer, lot number, or date/lot code.

3.5.2.5.3 Failure Reporting and Corrective Action System

a. The supplier shall establish and maintain a closed loop failure reporting and corrective action system (FRACAS) for reporting, analysis, and corrective action of failures occurring during the manufacturing and acceptance testing phases of tank production.

b. The FRACAS shall determine whether failures are caused by design deficiencies, human error, defective parts, test equipment, environmental exposure, or software.

3.5.2.5.4 Cleanliness Process

All wetted parts shall be cleaned in accordance with MIL-STD-1246 Level 50A prior to assembly. After demonstration of cleanliness at the piece part level, cleanliness will be maintained by requiring that gases, liquids, and fittings shall be maintained to this same level. Operations requiring cleanliness shall occur in a FED-STD-209 class 10,000 or better cleanroom.

3.5.2.5.5 Cleanliness Verification

There shall be no visible chips, slag, particulate matter, grease, or other foreign materials remaining in the completed parts or assemblies of the propellant tank. The propellant tank shall be cleaned by internally flushing using a minimum of 100 milliliters of test solvent per square foot of internal surface area (one square foot minimum sample size) in accordance with the guidelines of MIL-STD-1246 as listed in Table 3-1. The flushing sample shall be accompanied by agitation of the solvent over the entire surface area to be tested. The sample shall be immediately drained and filtered to meet the particle count requirements. A minimum of 200 milliliters shall be used if the parts have less than one square foot of surface area.

Table 3-1. Particle Size Maximum Allowable per 100 ml/ft^2 Surface

Particle Size (micron)	Number in Sample
5-15	166
15-25	25
25-50	7
> 50	1 (Non metallic)

3.5.2.5.6 Non Volitile Residue

A non-volatile residue (NVR) measurement shall be taken of the flushing fluid. The NVR shall be less than 1.0 mg/100 ml sample meeting the level A requirements of MIL-STD-1246.

3.5.3 Nameplate and Product Marking

The propellant tank shall be identified with the part number as depicted on the top assembly drawing, and each unit shall be serialized. The propellant tank components that are interchangeable shall be identified by part number and serial number or lot number.

3.5.3.1 Serialization

Each propellant tank shall have a different serial number. Serialization shall be accomplished without reference to configurations. There shall be no two propellant tanks with the same basic part number and the same serial number. Gaps between serial numbers are allowable, but the sequencing of serial numbers shall conform to the order of production of the components. No serial number shall be revised or changed after being assigned to a particular item.

3.5.4 Workmanship

Workmanship shall be of the highest quality consistent with the requirements of this specification. Particular attention shall be given to welding, wiring, marking of parts and assemblies, and freedom from burrs and sharp edges.

a. All parts and assemblies shall be designed and manufactured in accordance with NRL-approved process specifications or drawings.

b. All parts and assemblies shall be free of defects that would interfere with operational use, such as excessive scratches, nicks, burrs, loose material, contamination, and corrosion.

c. Equipment shall be manufactured, processed, tested, and handled such that finished items are of sufficient quality to ensure reliable operation, safety, and service life in the operational environments.

3.5.4.1 Latent Defects

The supplier shall be responsible for the repair or replacement of all tanks that are discovered to contain previously undisclosed defects in materials or workmanship.

3.6 Documentation

The program requires a minimum set of documentation for successful completion. The propellant tanks shall be fabricated and assembled in accordance with drawings, parts lists, processes, and other documents generated by the supplier. The supplier shall maintain these drawings/documents as required to provide assurance that the required propellant tank is producible. All documents used to produce the propellant tank require customer review and approval before use, and document changes after the original submittal require customer approval.

3.6.1 Drawings

a. Specifications and hardware shall be supported by drawings in accordance with MIL-DTL-31000 or NRL-approved equivalent.

b. The final system documentation shall be such that subsequent production items can be produced or procured that are essentially equivalent in all respects to those initially tested or delivered.

c. This final documentation shall also be adequate to allow the rapid incorporation of changes and modifications that have been approved by the procuring activity.

d. Documentation describing space segment operational procedures shall include contingency procedures to minimize the effect of possible on-orbit anomalies.

3.6.2 Interface Control Drawing (ICD)

The propellant tank ICD shall be furnished by the supplier with the technical proposal and maintained with current design information until product delivery.

3.6.3 Specifications

Specifications shall be prepared in accordance with MIL-STD-961 and the appropriate Data Item Descriptions (DIDs) or their NRL-approved equivalents. These documents shall be subject to change control procedures and proposed engineering change shall consider the effect of that change on these documents so that compatibility is maintained.

3.6.4 Test Plans

Test plans are to be furnished at the PDR and finalized at the CDR.

3.6.5 Test Procedures

Test procedure shall be available for customer review and approval at the CDR, and must be under configuration control, including NRL approval for changes, before the initiation of testing activities.

3.6.6 End Item Data Package

Each propellant tank shall be supplied with an end item data package that documents the propellant tank construction and test activities.

3.6.6.1 As-Built Documentation

Each propellant tank shall be supplied with a parts list, materials list, As-Built engineering drawings, and acceptance test procedures and data.

3.6.6.2 Build or Test Discrepancies

Shall be submitted with each propellant tank if applicable.

3.6.6.3 Failure Reports and Analysis

Shall be submitted with each propellant tank if applicable.

3.6.6.4 Log Book

The supplier shall prepare a log book for each tank delivered to the customer. The log book shall contain the complete test history of the propellant tank including a list of each pressure cycle, media used, and the test pressure.

3.6.6.5 Certification Statement

The supplier shall provide a certification statement reflecting the propellant tank’s compliance with this specification. The remainder of the documentation (part traceability information, complete build and test procedures, process specifications, equipment calibration, etc.) shall be maintained on file.

3.6.7 Qualification Report

A Qualification Report shall be submitted to the customer to document the design compliance with the requirements of this specification. The qualification summary report must reference qualification test data, and shall summarize test results and significance.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

Quality Assurance Requirements shall be implemented in accordance with MIL-Q-9858. This section describes the analyses, tests, and inspections required for the propellant tank verification process. Verification of the propellant tank design, construction, and performance will assure that the hardware and software conform to the requirements stated herein. The preferred method is test, where practical, to obtain empirical data to support verification. However, to meet program technical, schedule, and cost objectives, reuse of previously qualified flight equipment may dictate use of other verification methods (e.g., inspection, analysis). The analyses, tests, and inspections specified in Table 4-3 (included at the end of this section) will be conducted to verify that all requirements specified in Section 3.0 have been achieved.

4.2 Quality Assurance Program Requirements

The supplier's quality assurance program shall provide control of the following areas:

a. Reliability (paragraph 3.3);

b. Parts, materials, and processes (paragraph 3.5.2);

c. Workmanship (paragraph 3.5.4);

d. Nonconforming material (paragraph 4.3); and

e. Verification of design requirements (paragraph 4.4).

4.3 Quality Conformance

4.3.1 Control and Use of Nonconforming Material

Non-conforming material shall not be used without NRL approval. All nonconforming material used in the final product shall be adequately documented. Nonconforming material shall be stored in a controlled areas until disposition can be made.

4.3.2 Configuration Control

The propellant tank shall be fabricated and assembled in accordance with drawings, parts lists, processes, and other documentation submitted by the supplier for approval by the customer. The supplier shall maintain these documents as required to provide assurance that the propellant tank is reproducible. These documents shall be approved by the customer before use for fabrication or testing and shall not be modified without customer approval.

4.4 Verification of Conformance

The requirements of Section 3.0 shall be verified by one or more of the methods detailed in the Verification Requirements Checklist (Table 4-3). Verification will be documented using the Verification Matrix. The matrix will include a separate record for each paragraph. Each record will include the requirement, verification description, compliance data, and approval block. All verification documentation will be made available to inspection, test, and assessment personnel. Applicable supporting documentation including drawings, specifications, and procedures will be physically located at the verification site at the time of the requirement verification.

a. Analysis;

b. Inspection;

c. Test.

4.4.1 Verification by Analysis

A method of verification, taking the form of the processing and accumulated results and conclusions, intended to provide proof that verification of a requirement(s) has been accomplished. The analytical results may be based on engineering study, compilation or interpretation of existing information, similarity to previously verified requirements, or derived from lower level examinations, tests, demonstrations, or analyses. Analyses will be performed as specified in Table 4-3 to verify applicable requirements of Section 3.0. The analytical methods that may be used include engineering analyses in the specified technical discipline, similarity to a previously verified requirement, review of drawings and data, use of experience, or prior testing. When an analysis is specified in Table 4-3, a detailed engineering study to verify compliance with Section 3.0 of this document will be performed and documented.

4.4.2 Verification by Inspection

An element of verification consisting of investigation, without the use of special laboratory appliances or procedures, to determine compliance with requirements. Examination is nondestructive and includes (but is not limited to) visual inspection, simple physical manipulation, gauging, and measurement. Inspections will be performed as specified in Table 4-3 to verify applicable requirements of Section 3.0. These inspections are to be performed before unit qualification or acceptance testing as part of the normal quality control inspection process.

4.4.2.1 Inspection of Records

Validation of records is a method of verification that consists of a systematic review of all relevant records to demonstrate compliance with a requirement. This method occurs as part of the hardware and software buy-off process. For requirements verified by this method, the approved buy-off package will serve to certify verification. Verification by the review of design documentation is a method of verification that consists of a systematic review of design documentation to determine compliance with a requirement.

4.4.3 Verification by Test

A method of verification that employs technical means, including (but not limited to) the evaluation of functional operation by use of special equipment or instrumentation, simulation techniques, and the application of established principles and procedures to determine compliance with requirements. The analysis of data derived from test is an integral part of this verification method.

4.4.3.1 Responsibility for Tests

The supplier shall perform all or any of the verification requirements of this specification as directed in the purchasing documentation. Except as otherwise specified, the supplier may use its own or any other facilities suitable for performance of the inspection and test requirements specified herein, unless disapproved by the government. The FAME PMO reserves the right to perform any tests or inspections set forth herein when deemed necessary to ensure that supplies and services conform to prescribed requirements.

4.4.3.2 Test Oversight

All tests shall be subject to customer surveillance. Final acceptance shall be contingent upon written approval by the customer.

4.4.3.3 Test Procedures

Acceptance Test Procedures shall be submitted to the customer for approval prior to start of test. Test plans and procedures shall be documented such that testing can be performed by skilled engineering personnel. As a minimum, the procedures shall contain the following information:

a. A detailed step-by-step sequence specifying how each test will be performed. Include the applicable test conditions and tolerances such as pressure, temperature, time, voltage, current, and test media.

b. A description of test equipment used including name of instrument, manufacturer, model number, serial number, accuracy, and frequency of calibration.

c. Schematic of the test set-up.

d. An accept/reject criteria for each test requirement.

e. No use will be made of notations such as “OK”, check marks, “greater than”, or “less than” the test requirement to show that a requirement was met. The actual test data shall be recorded within the capabilities of the equipment.

f. Inclusion of a set of data sheets that lists the test paragraph number, parameter being evaluated, accept/reject criteria, actual test results, and inspection buy-offs.

4.4.3.4 Test Conditions

Unless otherwise specified, all tests shall be performed under ambient conditions of 30±2 inches of mercury atmospheric pressure, 70±25˚F temperature, and less than 90% relative humidity

4.4.3.5 Test Tolerances

Test conditions shall be controlled by the following tolerances except as otherwise specified. The temperature, humidity, pressure, acceleration, current, time, voltage, and flow rate shall be measured to ±5% of the nominal expected value.

4.4.3.6 Test Factors

A test factor of 1.05 over the design load shall be applied to any mechanical test other than pyrotechnic shock, acoustic, and random vibration.

4.4.3.7 Cleanliness

The propellant tank and all test equipment surfaces that contact the test media shall be certified clean in accordance with the requirements of paragraph 3.5.2.5.4 and 3.5.2.5.5. The propellant tank shall be protected by a 15 micron absolute filter during all qualification and acceptance testing. The filter shall be placed in the test configuration as close to the propellant tank as possible.

4.4.3.8 Test Media

Test media shall be helium, nitrogen, de-ionized water, isopropyl alcohol and Type I, Trichlorotrifluoroethane (Freon 113) in accordance with paragraph 3.2.2.3 specifications as required by the supplier.

4.4.3.9 Equipment Calibration

All measurements shall be made with instruments and equipment meeting calibration requirements of MIL-STD-45662. All instruments and equipment used shall conform to laboratory standards whose calibration is traceable to the prime standards of the National Institute of Standards and Technology. Equipment calibration records shall be available to the customer upon customer request.

4.4.3.10 Qualification Test

Qualification tests shall be conducted to demonstrate that the design and manufacturing methods used in the construction of the propellant tank have resulted in an item that meets the specified requirements and has suitable margins when exposed to the worst case operating environments. The following qualification tests shall be performed as detailed in the Qualification Test Sequence (Table 4-1). The propellant tank shall be qualification tested for flight in accordance with the requirements of this specification and MIL-STD-1522 and EWR 127-1.

4.4.3.10.1 Qualification by Similarity

The maximum use of qualification by similarity is anticipated. Qualification by similarity must justify both design and environmental similarity to apply. The applicability of a design's qualification by similarity will be determined by the customer based on a justifications established by the supplier.

4.4.3.10.2 Process Qualification Tests

Critical processes used in fabrication or testing of the propellant tank shall be qualified individually before use on the flight propellant tanks. Process qualification testing shall be representative of the process being qualified. For example welding process coupons shall be of the same material, thickness, and preparation as for the flight tank.

4.4.3.10.2.1 Test Coupons

A total of six test coupons for each critical process being qualified shall be provided to the customer. The customer reserves the right of independent inspection and verification of process conformance.

4.4.3.10.3 Development Tests

Development tests are not specifically required; however, the supplier should conduct sufficient tests or analysis as necessary to minimize cost and schedule risks to the program. Development tests or analyses that are performed shall be documented.

4.4.3.10.4 Tank Qualification Test Sequence

The qualification test shall be performed by the supplier according to a customer approved test plan generated by the supplier.

4.4.3.10.4.1 Static Acceleration

Verification will be conducted to assure compliance with paragraph 3.4.2.1.

4.4.3.10.4.2 Vibration

Verification will be conducted to assure compliance with paragraph 3.4.2.2.

4.4.3.10.4.3 Pyrotechnic Shock

Verification will be conducted to assure compliance with paragraph 3.4.2.3.

4.4.3.10.4.4 Thermal

Tests will be conducted to verify compliance with paragraph 3.2.5 as part of the range safety process.

4.4.3.10.4.5 Pressure Cycle

The pressure cycle testing of MIL-STD-1522 and EWR 127-1 shall be performed for the propellant tank design qualification.

4.4.3.10.4.6 Burst Pressure

The burst pressure testing of MIL-STD-1522 and EWR 127-1 shall be performed for the propellant tank design qualification. The minimum demonstrated burst pressure shall be 675 psig.

4.4.3.10.5 Identification of Development, Qualification Test, or Non-Traceable Items

These items shall be permanently and obviously identified with the words, “Test Only” to preclude use on a flight assembly.

4.4.3.10.6 Qualification Test Report

The qualification test results shall be submitted to the customer in the form of a report. The report shall include the following:

a. A narrative description of the test objectives

b. Synopsis and conclusions of the tests conducted, identity of the test procedures used, test results (data sheets and analog data), and any significant events pertaining to the tests. Digitally acquired data shall be appropriately summarized, stored by the supplier, and furnished for review by the customer upon request.

c. Identification and quantity of items tested, including part number, name, serial numbers, and design revision number.

d. Data of the test including schematics of the test set-up, test equipment used including make, model, serial number, accuracy, range, and certification data.

e. Photographs of test parts, test set-up, and any failures or discrepancies before, during, or after the testing.

Table 4-1. Qualification Test Sequence

Sequence	Test	Reference Paragraph
1	Static Acceleration	4.4.3.10.4.1
2	Vibration	4.4.3.10.4.2
3	Pyrotechnic shock	4.4.3.10.4.3
4	Thermal	4.4.3.10.4.4
5	Pressure Cycle	4.4.3.10.4.5
6	Burst Pressure	4.4.3.10.4.6

4.4.3.11 Acceptance Testing

Acceptance testing shall at a minimum be performed as detailed in Table 4-2. Acceptance tests detect deficiencies of workmanship, material, and quality, and demonstrate the electrical and mechanical performance of the unit or system to gain confidence that the unit has achieved the design capability. Acceptance testing (electrical and mechanical) shall be completed prior to beginning of qualification testing and the results provided to the customer. The supplier is encouraged to add testing to the minimums as presented. Acceptance test sequencing and detailed modifications can be approved individually by the customer.

4.4.3.11.1 Inspection of Product

Inspect each propellant tank for conformance to finish, envelope requirements from the ICD, freedom from damage, and correctness of markings. Perform 100% dye penetrant inspection of the weld heat effected zone in accordance with MIL-I-6866.

4.4.3.11.2 Weight

Record the weight of each propellant tank assembly. The weight shall not exceed the requirements of paragraph 3.2.8.4.

4.4.3.11.3 Volume Measurement

Measure the gas and liquid side volume of the propellant tank.

4.4.3.11.4 Proof Pressure

Apply ambient helium or nitrogen gas to the inlet and outlet port simultaneously to 563 +10/-0 psia. Maintain for five minutes minimum. There shall be no signs of damage, distortion, or yield.

4.4.3.11.5 NDI Inspection

Inspect each propellant tank, and particularly the welds, for damage during proof testing. Perform 100% dye penetrant inspection of the weld heat effected zone in accordance with MIL-I-6866.

4.4.3.11.6 Volume Measurement

Measure the gas and liquid side volume of the propellant tank. Compare pre- and post-proof pressure volumes for tank distortion; no distortion shall be permitted.

4.4.3.11.7 Random Vibration

Tests will be conducted to verify compliance with paragraph 3.4.2.2.

4.4.3.11.8 Internal Leakage

Pressurize the propellant tank outlet to 50 psig helium, record leakage at the gas inlet port after fifteen minutes with a mass spectrometer leak detector. The leakage shall not exceed 1 x 10^{-6} scc/sec.

4.4.3.11.9 External Leakage

With the propellant tank in a vacuum chamber, pressurize the propellant tank inlet and outlet port simultaneously to 450 psig with helium. The leakage shall not exceed 1×10^{-6} scc/sec when tested for fifteen minutes.

4.4.3.11.10 Cleanliness Verification

Verify that the cleanliness of the propellant tank has not been compromised since assembly. The propellant tank shall be vacuum dried after cleaning and verified to be dry before final packaging.

4.4.3.11.11 Final Inspection

Perform a final inspection of the propellant tank before packaging for shipment. Verify the ICD interfaces, and inspect the unit for workmanship.

Table 4-2. Acceptance Test Sequence

Sequence	Test	Reference Paragraph
1	Inspection of Product	4.4.3.11.1
2	Weight	4.4.3.11.2
3	Volume Measurement	4.4.3.11.3
4	Proof Pressure	4.4.3.11.4
5	Volume Measurement	4.4.3.11.6
6	Random Vibration	4.4.3.11.7
7	Internal Leakage	4.4.3.11.8
8	External Leakage	4.4.3.11.9
9	Cleanliness Verification	4.4.3.11.10
10	Final Inspection	4.4.3.11.11

Table 4-3. Verification Requirements Checklist

Requirement		Verification Method			
Paragraph No.	**Title**	**Not Applicable**	**Analysis**	**Inspection**	**Test**
3.0	REQUIREMENTS				
3.1	Item Definition				
3.1.1	Defining Characteristics				
3.1.2	Basic Function				
3.1.3	Intended Use				
3.1.3.1	Integration				
3.1.3.2	Testing				
3.1.3.3	Transportation				
3.1.3.4	Protection				
3.1.3.5	Propellant Loading				
3.1.3.6	Spin Balance				
3.1.3.7	Launch				
3.1.3.8	Transfer Orbit Operations				
3.1.3.9	Geo-Synchronous Mission Operations				
3.2	Performance Characteristics				
3.2.1	Design and Performance				
3.2.2	Operating Media				
3.2.2.1	Propellants and Pressurant Gasses				
3.2.2.2	Chemical Compatibility				
3.2.2.3	Fluids and Solvents				
3.2.3	Pressure Ratings				
3.2.3.1	Operating Pressure				
3.2.3.2	Reverse Pressure				
3.2.3.3	Outlet Port Pressurization				
3.2.3.4	Proof Pressure				
3.2.3.5	Burst Pressure				
3.2.3.6	Minimum Diaphragm Rolling Pressure				
3.2.3.7	Transient Line Pressures				
3.2.3.8	Cycle Requirements				
3.2.4	Propellant Expulsion				
3.2.4.1	Expulsion Cycles				
3.2.4.2	Expulsion Efficiency				
3.2.4.3	Diaphragm Differential Pressure				
3.2.4.4	Propellant Depletion				
3.2.4.5	Liquid Offloading				

Requirement		Verification Method			
Paragraph No.	Title	Not Applicable	Analysis	Inspection	Test
3.2.5	Thermal				
3.2.5.1	Operating Propellant Temperature				
3.2.5.2	Qualification Temperature				
3.2.5.3	Propellant Expansion				
3.2.5.4	Tank Resistance Heater				
3.2.6	Leakage				
3.2.6.1	Internal Leakage				
3.2.6.2	External Leakage				
3.2.7	Electrical Characteristics				
3.2.7.1	Electrical Ground Plane				
3.2.7.2	Electrical Bonding				
3.2.7.3	Electro-static Discharge (ESD)				
3.2.8	Physical Characteristics				
3.2.8.1	Tank Geometric Axis				
3.2.8.2	Z Axis Center of Gravity				
3.2.8.3	X, Y Plane Mass Imbalance				
3.2.8.4	Weight				
3.2.8.5	Volume				
3.2.8.5.1	Liquid Volume				
3.2.8.5.2	Gas Volume				
3.2.9	Interface and Envelope				
3.2.9.1	Detailed Mechanical Interface Control Drawing (ICD)				
3.2.9.1.1	ICD Configuration Control				
3.2.9.2	Tubing Interface				
3.2.9.3	Special Installation Requirements				
3.2.9.4	Tank Mounting Flange or Skirt				
3.2.9.4.1	Mounting Flange Alignment				
3.3	Reliability				
3.3.1	Shelf Life				
3.3.2	Operating Life				
3.3.3	Maintainability				
3.3.4	Interchangeability				
3.3.5	Safety				
3.3.5.1	Safety Compliance				
3.4	Environmental Conditions and Requirements				
3.4.1	Ground Handling, Integration, and Prelaunch Environments				
3.4.1.1	Transportation				

Requirement		Verification Method			
Paragraph No.	Title	Not Applicable	Analysis	Inspection	Test
3.4.2	Qualification Environments				
3.4.2.1	Static Acceleration				
3.4.2.2	Random Vibration				
3.4.2.3	Pyrotechnic Shock				
3.4.2.4	Integrated Qualification Testing				
3.5	Design and Contsruction				
3.5.1	Design Analysis Requirements				
3.5.1.1	Stress Analysis				
3.5.1.2	Failure Mode Determination				
3.5.1.3	Fracture Mechanics Safe Life Analysis				
3.5.1.4	Thread Design				
3.5.2	Parts, Materials, and Processes (PMP)				
3.5.2.1	PMP Plan				
3.5.2.2	Life Limited Items				
3.5.2.3	Parts				
3.5.2.3.1	Parts List				
3.5.2.3.2	Re-Use of Parts				
3.5.2.3.3	Structural Parts				
3.5.2.4	Materials				
3.5.2.4.1	Outgassing				
3.5.2.4.2	Structural Metallic Materials				
3.5.2.4.2.1	Material Properties				
3.5.2.4.3	Structural Safety Factors				
3.5.2.4.4	Prohibited Materials				
3.5.2.4.5	Dissimilar Metals				
3.5.2.4.6	Magnetic Materials				
3.5.2.4.7	Stress Corrosion				
3.5.2.4.8	Metal Finish Requirements				
3.5.2.4.8.1	Corrosion Resistant Steel				
3.5.2.4.8.2	Aluminum Treatments				
3.5.2.4.9	Prohibited Finishes				
3.5.2.4.10	Non-metallic materials				
3.5.2.4.11	Lubricants and Sealants				
3.5.2.4.12	Toxic Products and Formulations				
3.5.2.5	Processes				
3.5.2.5.1	Soldering, Welding, and Other Critical Processes				
3.5.2.5.2	Traceability Process				

Requirement		Verification Method			
Paragraph No.	Title	Not Applicable	Analysis	Inspection	Test
3.5.2.5.3	Failure Reporting and Corrective Action System				
3.5.2.5.4	Cleanliness Process				
3.5.2.5.5	Cleanliness Verification				
3.5.2.5.6	Non Volitile Residue				
3.5.3	Nameplate and Product Marking				
3.5.3.1	Serialization				
3.5.4	Workmanship				
3.5.4.1	Latent Defects				
3.6	Documentation				
3.6.1	Drawings				
3.6.2	Interface Control Drawing (ICD)				
3.6.3	Specifications				
3.6.4	Test Plans				
3.6.5	Test Procedures				
3.6.6	End Item Data Package				
3.6.6.1	As-Built Documentation				
3.6.6.2	Build or Test Discrepancies				
3.6.6.3	Failure Reports and Analysis				
3.6.6.4	Log Book				
3.6.6.5	Certification Statement				
3.6.7	Qualification Report				

5.0 PREPARATION FOR DELIVERY

This section provides guidance for preparing the propellant tank for delivery. The propellant tank shall be packaged such that transportation and storage conditions do not become design considerations.

5.1 Packaging and Processing

Unless otherwise specified, the supplier shall be responsible for the preservation and packaging of the propellant tank in a manner that will prevent contamination, corrosion, deterioration, and physical damage and ensure safe delivery in good condition.

5.1.1 Protection of Cleanliness

Inlet and outlet ports shall be suitably protected by the use of hard non-abrading caps or plugs and or plastic film wraps to prevent migration of foreign particles and to protect the mating surface from damage during shipment.

The cleaned tanks shall be packaged in a primary and secondary sealed contamination barrier. These barriers may be plastic film wraps or plastic bags. All packaging materials must be as clean as the tank that it is protecting.

5.1.2 Marking for Cleanliness

The cleaned, packaged propellant tank shall be identified by a suitable tag or label that shall be legible without degradation of the cleanliness preservation means. The tag or label shall contain the following minimum information:

a. Hydrazine Propellant Tank

b. Supplier name

c. Supplier part number

d. Supplier serial number

e. Date of cleaning (month/day/year)

f. Specification to which tank is cleaned

g. Cure date or assembly date (when applicable)

5.1.3 Marking for Shipment

Each individual container shall be durably and legibly marked or labeled per MIL-STD-129 with the following minimum information:

a. Hydrazine Propellant Tank

b. Supplier name

c. Supplier part number

d. Supplier serial number

e. Customer purchase order number

5.1.4 Crate Labels

Crated tanks shall be labeled to indicate which side should be opened for inspection of products and documentation.

5.2 Packaging and Transportation

After completion of acceptance testing, the propellant tank shall be cleaned, dried, and packaged for shipment to the customer in accordance with Level B of MIL-STD-794.

5.2.1 Preparation of Qualification Tested Tanks

The tanks delivered as Qualification Test Tanks shall be prepared for delivery as stated in paragraph 5.2 with the exception that the cleanliness is limited to drying tanks of all moisture, wiping tanks of foreign materials, and protection of these elements by normal commercial practices.

5.3 Containers

The supplier shall use customer approved industry standard containers suitable for aerospace components or electronics for the packaged items.

5.4 Shipment Carrier

Unless otherwise specified, the supplier shall use Federal Express overnight air freight for deliveries to the customer.

6.0 NOTES

This section provides additional information that is not contractually binding. Included are a glossary and list of acronyms.

6.1 Definitions

6.1.1 Supplier

The supplier shall be an organization awarded a contract to supply a product or service.

6.1.2 Customer

The customer shall be the organization who awarded the contract.

6.1.3 Production Hardware

Hardware fabricated and inspected to production drawings, identical in performance, configuration, and fabrication to the article to be flown.

6.1.4 Interchangeable Items

When two or more items possess such functional and physical characteristics as to be equivalent in performance and durability and are capable of being exchanged one for the other without alteration of the items themselves or of adjoining items except for adjustment, and without selection for fit or performance, the items are interchangeable.

6.1.5 Replacement Item

An item that is functionally interchangeable with another item, but which differs physically from the original part in that the installation of the replacement part requires operations such as drilling, reaming, cutting, filing, shimming, etc. in addition to the normal applications and methods of attachment.

6.1.6 Part

One piece or two or more pieces joined together that are not normally subject to disassembly without destruction of designed use.

6.1.7 Device

Electromechanical or mechanical items that perform a specific function and are intermediate in complexity between piece parts and components. For example: valves, small motors, relays, gyros, connectors, vidicon tubes, batteries, etc.

6.1.8 Component

A combination of parts, devices, and structures, usually self-contained, that perform a distinctive function in the operation of the overall equipment; i.e., a “black box.”

6.1.9 Operating Failure Rate

The operating failure rate represents a mathematical combination of failure rates associated with a part’s failure modes that may occur in an operation sequence under laboratory conditions.

6.1.10 Cycle

A cycle (e.g., thermal vacuum testing) shall be defined as the transition from a nominal to a positive or negative extreme, and the transition to the opposite extreme and back to nominal.

6.1.11 Qualification

Conducted on an item representative of a Test production unit to verify that the released design and production methods result in a product that meets performance and design requirements established by contract, specification and/or engineering drawing.

6.1.12 Acceptance

Conducted to measure the product performance test characteristic and to verify conformance to selected design requirements as a basis for acceptance (normally conducted on each item to confirm acceptability, except where minimum lot sampling is specified).

6.1.13 Analysis

Verification by qualitative or quantitative evaluation of data to determine that the item will meet specified requirements. Analysis techniques may include systems engineering analysis, statistics, analog modeling, computer simulation, review of drawings, etc.

6.1.14 Inspection

Verification by comparison of physical characteristics to specified design requirements. Inspection is normally used to verify construction features, workmanship, physical conditions, or requirements, e.g., physical dimensions, marking, wire coding, surface finish, etc.

6.1.15 Similarity

Verification by evaluation of analytical or test from an analysis or test program for an item which is sufficiently similar to the required item for the data to be valid. The data must show that the item used as a basis for verification has satisfied equivalent or more stringent requirements. Similarity is not shown as a drawing requirement but is negotiated separately to satisfy specific requirements.

6.2 Acronyms and Abbreviations

°F	Degrees Fahrenheit
AKM	Apogee Kick Motor (See also SRM)
BOL	Beginning of Life
CDR	Critical Design Review
CVCM	Collected Volatile Condensable Material
dB	Decibel
DID	Data Item Description
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FAME	Full-sky Astrometric Mapping Explorer
FRACAS	Failure Reporting and Corrective Action System
ft/sec^2	Feet per Second Squared
g	Acceleration due to gravity
GSE	Ground Support Equipment
ICD	Interface Control Document
in-Hg	Inches of Mercury
KSC	Kennedy Space Center
MEOP	Maximum Expected Operating Pressure
Mg	Milligram

Micron	One millionth of a meter
MIDEX	Medium Class Explorer
N_2H_4	Anhydrous hydrazine
NCST	Naval Center for Space Technology
NRL	Naval Research Laboratory
NVR	Non-Volatile Residue
OSHA	Occupational Safety and Health Administration
PDR	Preliminary Design Review
PMO	Project Management Office
PMP	Parts, Materials, and Processes
psia	Pounds per square inch absolute
psid	Pounds per square inch differential
psig	Pounds per square inch gauge
RMS	Root mean square
scc	Standard cubic centimeters
sec	Seconds
SRM	Solid Rocket Motor
TDI	Time Delay Integration
TML	Total Mass Loss
Torr	A unit of pressure measurement equal to 1/760 of an atmosphere
USNO	United States Naval Observatory